THE AGE OF THE EARTH.

SINCE physicists do not seem to be in complete accord on the question of the time which has elapsed since the earth first permanently crusted over, it may perhaps be as well to investigate the evidence to be obtained from a study of stratified deposits.

One of the first to raise a remonstrant voice against the philosophers who demanded practically unlimited time was Sir Archibald Geikie, whose original discussion of the data known regarding the present working of rivers gave us the fraction $\frac{1}{6000}$ as representing the annual rate at which the Mississippi is lowering its basin. The surprise with which this result was received is now almost forgotten, in an unquestioning acceptance. The question of the rate of deposition was next treated by Dr. Haughton, in the year 1880, with his usual mathematical severity. Dr. Haughton, however, preferred to take into consideration six other great rivers besides the Mississippi, and thus obtained the fraction $\frac{1}{3090}$ as representing the average thickness of rock which is annually worn away from the terrestrial surface by the denudation of rivers. But the proportion of sea-bottom to land surface is as 145 : 52, so that if the suspended sediment be spread evenly over the sea-floor, the average rate of accumulation will be $\frac{1}{8616}$ of a foot per annum. The maximum thickness of the stratified series was estimated by Dr. Haughton to be 177,000 feet, and thus if the rate of deposition in the past was on the whole uniform and the same as that of the present, this thickness of rock would have required a period of 1,526,750,000 years for its accumulation. Dr. Haughton is not a uniformitarian, consequently he divided this number by 10. Dr. Wallace next made what must be considered a great step in advance, by pointing out that the sediment which is carried into the sea is not deposited uniformly over the whole sea-floor, but, as the *Challenger* dredgings clearly showed, along a comparatively narrow marginal tract. Instead, therefore, of multiplying $\frac{1}{3090}$ (the yearly rate of denudation) by $\frac{52}{145}$, he divided it by $\frac{1}{19}$ (the proportion of the area of maximum deposition to the area of denudation), and thus obtained 28 millions as the number of years required for the accumulation of 177,000 feet of rock.

A further correction was next made by Mr. C. Davison, who showed that the fraction $\frac{1}{3090}$ is obtained by an error in arithmetic, and that the true value is $\frac{1}{2400}$. Introducing this fraction into Mr. Wallace's calculation, we obtain in round numbers 22 millions of years, a close approximation to the result, deduced from physical considerations, by Mr. Clarence King.

Of late years considerable additions have been made to our knowledge of the thickness of the systems of stratified rock, and I present the following table as representing the maximum thickness of all known formations down to the base of the Cambrian, a definite horizon marked, as is well known by the occurrence of fossil remains of most of the great subdivisions of the Invertebrata:—

System.	Thickness in feet.	First appearance of
Cambrian	16,000	
Ordovician	14,000	
Silurian	14,000	Fish
Devonian	20,000	
Carboniferous	21,000	Amphibians
Permian	12,000	Reptiles
Trias	13,000	Mammals
Jurassic	8,000	
Cretaceous	14,000	
Eocene	12,000	Eutheria
Oligocene	12,000	
Miocene	6,000	
Pliocene	2,000	
	164,000	

The total thickness is 164,000 feet, lying in a fairly continuous series, and calculating by Mr. Wallace's method, this leads to the conclusion that, in round numbers, 21 millions of years have elapsed since the beginning of Cambrian times. The truth of Mr. Wallace's argument depends on the assumption that an area of maximum deposition retains a constant position during the existence of a geological system. This is no doubt approximately the case, but so far as it is not, the deviation from stability will render Mr. Wallace's estimate deficient. On the other hand, as Mr. Wallace himself recognised, the area of maximum deposition does not extend uniformly round the coast line, but is concentrated, if one may so speak, near the mouths of rivers: the effect of taking this into account will far more than compensate for any shifting of the area. It is unnecessary to do more than point out that deposits, where they attain their maximum thickness, are of a more or less deltaic nature, and were probably deposited near the mouth of large rivers, in seas more or less land-locked. From investigations in which I am now engaged, I am led to conclude that where systems attain their maximum thickness, accumulation may have proceeded at the rate of one foot in a century, or even more rapidly.

The question largely depends on the relative size of areas of denudation and deposition: an objector to my estimate may urge that accumulation at this rate involves the existence of areas of denudation of much larger dimensions than the map will find room for. It is worth while to inquire into this, and a single example will suffice. Let us consider the coal measures of the British Isles. Suppose they cover, to the depth of half a mile, a circular area 300 miles in radius, having its centre somewhere over Anglesey, their volume will thus be 141,372 cubic miles; add to this 15,876 cubic miles for the deposits of greater thickness occurring over the North of England, and South Wales and Somersetshire. This gives a total thickness of 157,248 cubic miles. But since the maximum thickness is 12,000 feet, these will have accumulated, according to our assumption of 1 foot in a century, in 1,200,000 years. The coexistent area of denudation affords $\frac{1}{2400}$ of a foot of sediment per annum, or ·00000008 cubic mile per square mile yearly. In 1,200,000 years this will amount to nearly $\frac{1}{10}$ cubic mile per square mile; and thus the 157,248 cubic miles of sediment in the coal measures will have required a land surface 1,572,480 square miles in area for their supply. This will be represented by a circular area with a radius of 707 miles, and that an area of land several times these dimensions may have existed north and west of the British Isles during carboniferous times, is an assertion which most geologists will be prepared to defend.

So far as I can at present see, the lapse of time since the beginning of the Cambrian system is probably less than seventeen millions of years, even when computed on an assumption of uniformity, which to me seems contradicted by the most salient facts of geology. Whatever additional time the calculations made on physical data can afford us, may go to the account of Pre-Cambrian deposits, of which at present we know too little to serve for an independent estimate.

No one can regard without satisfaction the introduction into Lord Kelvin's argument of well-ascertained data as regards the melting points and other properties of rocks. Dr. Joly finds the melting point of basalt to be even lower than that of diabase, viz. 815° C., a result in accordance with that found by other investigators. These facts, though of great assistance in supporting the short chronologists of the earth's age, may prove embarrassing when the question of the physical state of the interior of the earth is ready for reconsideration. Dr. Joly finds the value of dt/dp for basalt to be 0·006, and for diabase, according to Carl Barus, it is 0·021 at 1200° C.; in either case the temperature gradient gains on the melting point gradient rapidly enough to show that, at no great distance beneath the surface of the earth, the interior, if it consist of such rocks as these, is in a state of liquidity. Geologists in general would probably be glad to purchase an internal liquid shell at a cost of several millions of years. Would not however, the admission of the existence of liquid shells in the interior of the earth, deprive the mathematical argument, as at present formulated, of all validity?

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